Stitch Plug Repair for Self-Reacting Friction Stir Weld Closeouts

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How Do You Repair a Repair?

Upon the completion of a circumferential Self-Reacting Friction Stir Weld (SR-FSW) an exit hole is left upon withdrawal of the pin tool. A plug is used to seal this hole varying in size from a M3 (small) or M5 (medium) based on the thickness of the weldland. Upon its completion, each plug weld undergoes Non-Destructive Evaluation (NDE). Many defects can be associated with plug welds such as cracks or porosity inside the weld due to insufficient cleaning, revolutions or load. Currently, if a defect is found the entire plug is removed and replaced with a larger "repair" plug. Upon its completion, repair plugs are subjected to the same NDE criteria. If a defect is found in the repair weld then another repair must be made. Instead of completely removing the repair plug, it is thought to remove only the defect of the said plug. This is achieved by offsetting the hole to only remove the defect thus placing a "stitch" plug at a predetermined offset. Results show similar strengths are achieved when compared to the original closeout plug. Stitch plugs can be used as a 1st option repair technique or to "repair a repair."

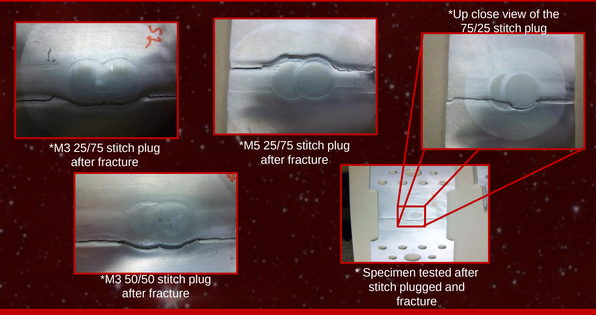
Abstract

The purpose of this study is to determine the effects of an offset oriented pull plug "stitch" weld after closing out the circumferential self-reacting friction stir weld. A stitch plug is used to repair a defective plug at the location of the defect. The stitch plug is positioned at different offsets (percentage of diameter) known as, 25/75, 50/50, and 75/25. Several plug sizes and offsets were evaluated under different testing conditions. Each specimen was subjected to mechanical testing, metallographic analysis and NDE. The results of each offset were compared and evaluated. A control was used for comparison to ensure strength requirements are being met.

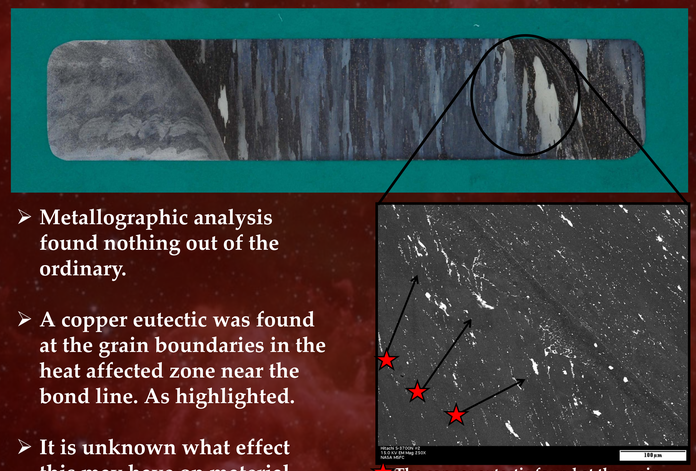
Variables of Interest

- *Y - Region* - The "y" region is described as the area between the two intersecting circular plugs (one being the original one being the stitch) where the tangents of each plug make an angle.
- *Plug Size* - The relative plug sizes are M3's which have a hole diameter of 0.813" and M5's which have a hole diameter of 0.875".
- *UTS* - This is the Ultimate Tensile Strength of the plug welded specimens This is the response factor for each variable.
- *Specimen Width Ratio* - The material ratio is obtained by using the width of the two intersecting circular plugs for each plug offset divided by the fixed width of the specimen tested. The surrounding weld is also considered.
- *Temperature* - The specimens are tested in various temperatures to simulate real life situations. One be normal room temp. (72), another being LN2 (-320), and finally LH2 (-423)
- *Initial Weld Panel* - All plug specimens were welded in an initial weld configuration of 0.208" 2014/2219 SR-FSW. Three plug specimens were welded in each of the (24) panels totaling (72) test
- *Plug Material* - All plugs were made from AL 2219 extruded rod.
- *25/75 Plug Offset* -This offset is described as 25% of the stitch plug diameter is overlapping the original plug diameter.
- *50/50 Plug Offset* - This offset describes the 50% of the stich plug diameter that is overlapping the original plug diameter.
- *75/25 Plug Offset* - This offset is determined by the overlapping of 75% of the stitch plug diameter over the original plug.

Fracture Examination



Metallographic Analysis



- Metallographic analysis found nothing out of the ordinary.
- A copper eutectic was found at the grain boundaries in the heat affected zone near the bond line. As highlighted.
- It is unknown what effect this may have on material properties

★ The copper eutectic found at the grain boundaries in the heat affected zone near the bond line blown up.

Plug Offset Observation

*** Brief Description***
Investigated three offsets and two plug sizes M5 and M3. The offset overlap and plug sizes determine the Stitch Width dimensions and Y region angles

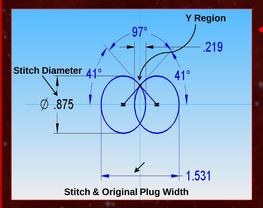
M5

- M5 - This is the larger of the two stitch plugs. The hole diameter of this plug is 0.875". This larger hole increases its specimen width ratio.

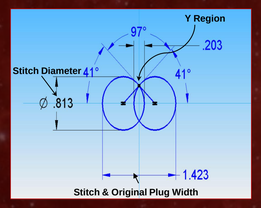
M3

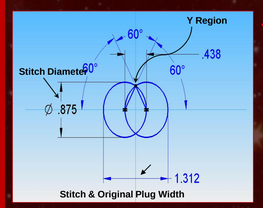
- M3 - This plug is the smaller of the two stitch plugs. The hole diameter of this plug is 0.813". This smaller hole reduces its specimen width ratio.

- Y Region - The varying M3 and M5 plug size has no effect on the Y Region angle, unlike its offset counterpart. Using a CAD program the is found.

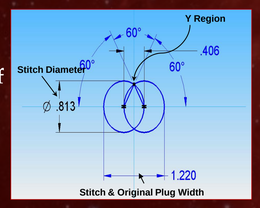


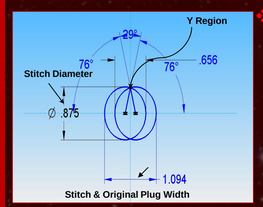
- 25/75 - This theoretical offset is described as 75% of the stitch plug diameter is overlapping the original plug diameter.



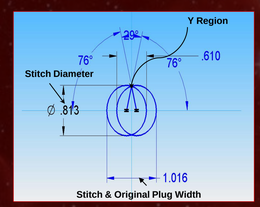


- 50/50 - This theoretical offset is described as 50% of the stitch plug's diameter is overlapping the original plug diameter.





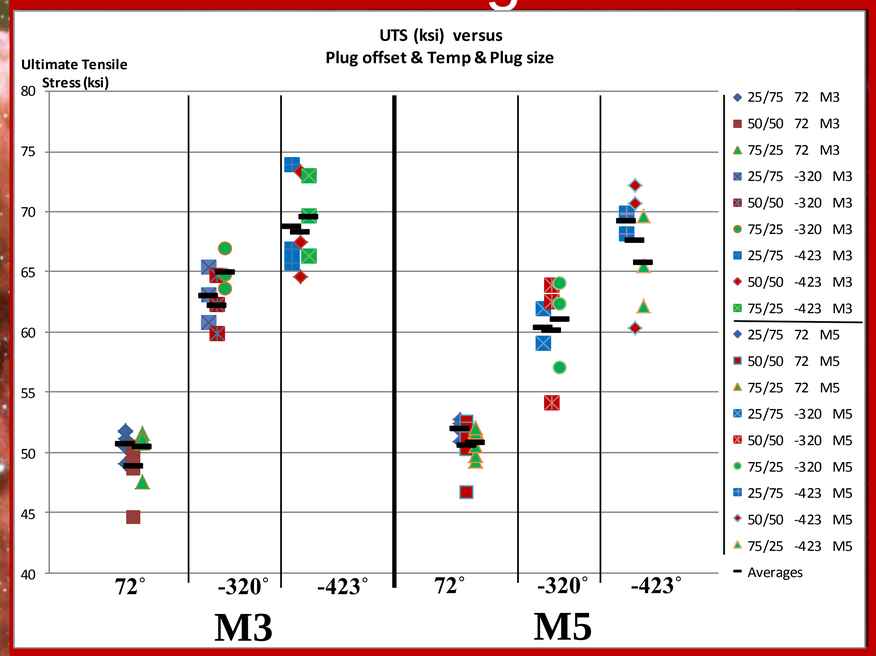
- 75/25 - This theoretical offset is described as 75% of the stitch plug's diameter is overlapping the original plug diameter.



Non Destructive Evaluation

- Non Destructive Evaluation was done no significant flaws were detected.
- Phase Array Ultrasonic Testing (PAUT)
- Penetrant Testing (PT)
- Eddy Current Testing (ET)

Stitch Plug Data



Conclusion/Discussion

The plugs sizes and the comparative plug offsets seem to have no effect on the ultimate tensile strength. According to the data shown above the M5's and M3's are similar in both offset and size relative to strength. As shown in the graph above the plug offset orientation makes little difference in strength relative to its specific temperature range, the plug offsets are grouped together with their averages for comparison for each plug size. As the temperature increments get colder the strength increases due to the enhancement factor of cryogenics. The unique variables of each plug such as, Y angle, Specimen Width Ratio and offset still pose the same results when compared to both sizes. The plots indicate each specimen configuration average is within family of all similar tests.

LH2 (-423 F) = 65-70ksi LOX (-320 F) = 60-65ksi RT (72 F) = 48-53ksi

Future Work

Future work in this study is promising. Suppose instead of placing the stitch plug 180 degrees or side by side with the repair plug, we place that stitch plug on a 45 degree or 90 degree angle orientation. Using these different angles of placement such as 45 or 90 degrees but, still using the same concept of offsets i.e. 25/75, 75/25, 50/50. This will allow stitching to be done wherever a defect tends to appear, Using the best offset for that particular defect.

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